

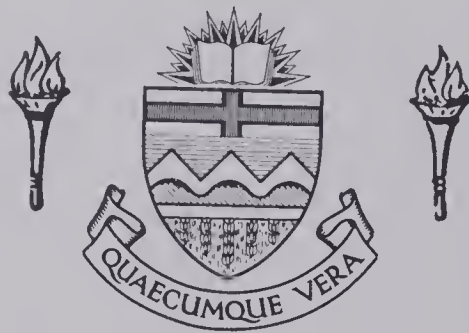
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INCREASING TORQUE AS A KINESTHETICALLY DEPENDENT
VARIABLE IN SHORT-TERM MEMORY

by



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A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Increasing Torque as a Kinesthetically Dependent Variable in Short-Term Memory," submitted by Frank Alexander Carre in partial fulfillment of the requirements for the Degree of Master of Arts.

ABSTRACT

The purpose of this study was to investigate the effects of increasing torque as a kinesthetically dependent variable on the apparent storage disparity between visual and kinesthetic cues in short-term memory (STM). The simple motor task consisted of reproducing a predetermined pressure position by rotating the handle of a crank which compressed a torsion spring producing an increasing torque.

The three main effects in the $3 \times 3 \times 2$ experimental design were STM, increasing torque, and sensory modality. The main effect factors considered for STM were; immediate recall, delayed recall (ten seconds), and delayed recall with an interpolated task (counting backwards aloud by three's, from 100, for ten seconds), for increasing torque; low - 'two and one-half pound-feet', medium - 'five pound feet', and high - 'ten pound-feet', and for sensory modality; visual (without goggles) and kinesthetically (with goggles). Nine grade XII high school students were tested on all eighteen conditions dictated by the experimental model. Each condition had five randomized replications resulting in ninety trials per subject.

The results, as analyzed by a three-way analysis of variance showed that reproduction accuracy on an increasing torque motor task does not appear to follow the same STM paradigm as for simple verbal tasks. The subjects seemed to attend to the difference in increasing torque level as an important information source in task reproduction. This attention seemed to suppress visual cuing, as absolute mean error scores were almost identical for both visual and kinesthetic modalities.

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CHAPTER I

STATEMENT OF THE PROBLEM

I. INTRODUCTION

Human performance theory studies the performance limitations of human beings. It utilizes the logic, language, and mathematics of information and communication theory (1). By analyzing the processes involved in skilled performance and skill development, and by establishing quantitative estimates of human abilities, predictions about man's capacity to perform complex tasks are possible (2).

The study of perceptual-motor skills in terms of human performance theory is an attempt to predict and control human response (3). Researchers are analyzing skills in terms of their component parts with the emphasis on the ability of these selected parts to predict, within well construed limits, the total skill. The pyramiding of these results leads to a comprehensive analysis of the task involved.

The study of skilled performance in a logical manner helps to determine the best possible methods of learning a motor task. These methods will then provide maximal benefit for the physical educator, coach, and performer. Wilberg (4) has categorized some of the variables present in perceptual-motor skills as: rate, length, and complexity of input; temporal and event uncertainty; retention time; and rate, length, and complexity of the overt response. Fitts and Posner (2) consider the basic characteristics of skilled performance to be organization, goal directedness, and utilization of feedback. The

transformation of these variables into usable information occurs when man applies his memory to elaborate upon a stimulus (2).

A major difficulty in studying human memory however, is that it is not possible to obtain systematic physiological information regarding ideation and memory. This limits the study of memory to a determination of performance based upon a variety of memory tasks. From these results, the functional operations performed by the subject in order to produce the observed performance are deduced (5). A further difficulty in human learning is that an individual's ability for different tasks varies (6). These delimitations in the study of human skill have led psychologists to adopt the 'little black box' approach in the analysis of complex systems (7). Utilizing the concepts of information theory, the capacity of the human perceptual-motor system and its properties can be inferred from a knowledge of the input and resultant output patterns (8).

Gagne and Fleishman (9) state that learning results from the storage of a number of 'differential habits' in memory. The learning of a motor skill then, involves the transformation of new input, and retention of previous information from the memory store. This view is similar to Crossman's (10) contention that motor performance is dependent on the loadings of the decision and effector mechanisms, and the intrarelationship of time to the external conditions. Environmental perception by means of the sensory modalities, generally supplies the fundamental knowledge of the surrounding situation. This information, both on an initial and a feedback (consequential) basis is necessary in human motor operations. The feedback information may be kinesthetic or exteroceptive (10).

Kinesthesia presumably monitors the muscular components of performance, and may provide the performer with some indication of probable results before he can see the observable input. Eliminating all forms of feedback to the memory store would make learning impossible (11).

The amount of information to be processed can affect the rate at which learning takes place. There appears to be a limit however, on our capacity for unidimensional judgments; which varies, but remains fairly stable for a wide variety of stimuli (12).

II. THE PROBLEM

The importance of memory in performance has long been recognized by psychologists (13). Memory is usually divided into two well conceived forms. These are long-term memory (LTM) and short-term memory (STM). It is only within the last ten years or so however, that much emphasis has been placed on the STM construct (14). It is this STM system which can provide information about 'the present state of the performer' (15). STM decays rapidly without rehearsal, and is constantly being replenished with new information as the situation changes.

The investigation of the storage mechanism in STM has, in the past, largely been concerned with visual cues and their resultant verbal coding. Recent studies by researchers such as Adams and Dijkstra (16) have also been concerned with perceptual-motor performance.

Posner (17) showed that in the absence of sustained attention (due to an interpolated task), visual and kinesthetic cues were not retained in the same fashion in STM. Posner's findings provide a strong argument

for more than one method of processing and/or storing information in STM. Wilberg's (18) study involving the kinesthetic factor of constant pressure (torque), and visual cuing in STM found no indication that constant pressure supplied any observable information in the performance of a simple motor task. His results served to negate the view that the kinesthetic factor of constant pressure is of importance in the reproduction of a simple performance skill.

In order to confirm or disprove the existence of different storage and/or processing capacities in STM the effects of a number of other kinesthetic factor loadings and visual cues must be studied. The major problem of this study was to analyze the effect of 'increasing pressure' (torque) as a kinesthetically dependent variable on the apparent storage disparity between visual and kinesthetic cues in STM.

III. IMPORTANCE OF THE STUDY

Physical educators are constantly searching for information about human performance which will help them deal more effectively with the teaching of motor skills. Much work has been done on the physiological factors of motor performance, but little has been achieved in the complex area of psychophysical performance which can be directly applied by the practitioner. Memory is a vital factor in learning, and any knowledge of its capacities and capabilities will be of importance in understanding human performance.

The significance of kinesthesia to learning and STM is not clear at the present time (18). Whether kinesthetic cues (internal stimuli)

can be substituted for visual cues (external stimuli) as the motor task increases in complexity is critical to the teaching of physical education (9). A greater understanding of the role played by visual and kinesthetic cues in STM has distinct relevance for learning theory as it applies to perceptual-motor skills.

IV. DEFINITIONS

For the purposes of this study it is necessary to define several key terms. They do not necessarily apply outside the context of the study.

Kinesthesia. The particular mental sensation produced by the gripping and moving of a rotary handle. Visual and auditory input are totally absent from this motor movement.

Short-term Memory.

A system which loses information rapidly in the absence of sustained attention. Short-term memory involves about the first sixty seconds after presentation of a new stimulus. After that time, either the items are lost or they are transferred to a long-term memory system (2).

Experimental Main Effects. Refers to the three primary components examined in this study. These effects are short-term memory, increasing torque, and sensory modality.

Experimental Factors. Refers to the predetermined experimental levels categorized from the main effects. They include; STM (immediate recall, delayed recall, and delayed recall with an interpolated task), increasing torque (low - 'two and one-half pound-feet', medium - 'five pound-feet', and high - 'ten pound-feet'), and sensory modality (vision

and kinesthesia).

Experimental Conditions. Refers to the eighteen combinations of the experimental factors dictated by the 3 x 3 x 2 paradigm employed in the study.

V. LIMITATIONS

1. This study is limited to the retention of new information over a relatively brief initial period of the STM system.
2. The sensory modalities concerned with in this study are limited to those of vision and kinesthesia.
3. Kinesthesia is restricted to that sense produced by blindly moving a handle in a rotary movement task.
4. Only right handed, male subjects attending grade XII at Ross Sheppard Composite High School in Edmonton, Alberta were used in the study.

CHAPTER II

REVIEW OF THE LITERATURE

I. INTRODUCTION

Research in the area of short-term memory (STM) has been primarily concerned with verbal material (20). Broadbent's (21) information processing model of STM suggests, however, that motor skills might differ from verbal tasks in their requirements of the central processing capacity. Posner (1) (17) (19) has pioneered the investigation of this premise.

The literature reviewed in this section was limited to those aspects of STM and kinesthesia considered pertinent to the study. Articles reviewed were categorized and synthesized under major framework headings to facilitate documentation and analysis.

II. SHORT-TERM MEMORY

Concept of Short-Term Memory

Human memory studies are important to human performance theory as all skill learning requires some storage of information (2). Melton (13) contends, "... psychological studies of human STM, and particularly the further exploitation of new techniques for investigating human STM, will play an important part in the advance towards a general theory of memory." This statement indicates the importance of memory as an essential part of learning theory.

Experimental studies of immediate memory were being conducted for many years before two recent trends led to a fresh approach in the field (22).

1. The application of concepts drawn from information theory.
2. Recent neurological theories of memory processes.

Miller's (12) discussion of human channel capacity indicates a limitation to the amount of information which can be assimilated at any one time. He states that input information may be amplified by increasing the rate of stimulus presentation or increasing the number of alternative stimuli. The amount of information which man can transmit and process, according to Miller, is approximately 2.5 'bits' for unidimensional judgments. He also distinguishes between bits of information as the measuring unit for 'absolute judgment' and 'chunks' of information as the unit of measurement of human information-processing capacities for STM. "The span of immediate memory seems to be almost independent of the number of 'bits per chunk' " (12). This would indicate that since the memory span is a fixed number of chunks, it is possible to increase the bits of information it contains by building progressively larger chunks. This process is called 'recoding'. Schaub and Lindley's (23) study on the effects of recoding cues on STM utilized high and low-meaningfulness trigrams. Their results seem to support the chunking postulate, and they conclude, "... efficient recoding associations have a beneficial effect upon recall presumably by increasing the amount of chunking that takes place."

Posner (19) considers STM to consist of three fairly distinct aspects. They are:

1. The retention of new information over relatively brief periods of time.

2. The relatively direct representation of the stimulus.
3. The concept of an 'operational memory' for LTM information which is activated in the process of solving a particular problem.

Postman's (24) categorizations for STM closely paralleled those proposed by Posner. They comprise:

1. The forgetting mechanism which starts almost as soon as the stimulus has been perceived.
2. The limitations on human capacity for immediate reproduction of the stimulus.
3. The concern with selective mechanisms which determine the retention of certain items and their relative order of reproduction.

The area of major importance for this study is item three.

Brown (25) proposed the theory that forgetting was a function of redundancy, and the more redundant the information in an item, the longer it would be remembered. He later suggested that while the physiological basis of memory was unknown, it is usually assumed "... that storage involves either changes in synaptic resistances or the creation of reverberating activity within neural loops" (26).

One of the issues in a general theory of memory has been the comparison of retention processes involved in storage of the memory trace in STM and LTM (13). The actual mechanism in STM which causes such rapid forgetting in the absence of rehearsal is not clear. Decay proponents (24, 25, 26, 27) contend that the decay of a stimulus trace begins when rehearsal is prevented, and is generally a function of time. Those supporting the interference theory (13, 28, 29, 30) have shown that despite prolonged distraction, forgetting does not always follow rehearsal prevention. In fact, Keppel and Underwood (28) demonstrated that on the first trial of a memory experiment only small differences in retention occurred between three and eighteen seconds of an interpolated task;

while after two or three trials, preventing rehearsal caused a rapid decline in performance. In interference theory memory traces are considered permanent except when they are overshadowed by stronger competing traces or new traces.

In summary, the decay theorists contend that STM deteriorates rapidly due to the time lapse between memory traces, resulting in a dicotomy between STM and LTM. In contrast, interference theory holds that retention is related to the similarity of the interfering trace to be learned, which indicates a continuum between STM and LTM (31). Most researchers accept the premise that both decay and interference theory are necessary to account for the rapid forgetting in STM and important sources of interference are 'retroactive inhibition' and 'proactive inhibition' (26).

Retroactive Inhibition

This form of forgetting, is an effect of ensuing experience upon previous learning. The greatest effects of this kind appear to occur when the ensuing experience involves exposure to the same kind of material involved in learning (32).

Eriksen and Steffy (33) investigated the effects of STM and retroactive inhibition (RI) in visual perception. In one experiment they analyzed four male subjects over twelve different experimental sessions permitting an analysis by subjects. The first experimental stimulus was a short presentation of a display card consisting of a random pattern of X's and O's arranged in a circular pattern. At predetermined intervals after the display (ten - 700 milliseconds) an arrow would appear indicating a position on the preceding display. The subject reported whether the position had contained an X or an O. This study revealed definite

individual differences in the effect retroactive inhibition had on STM.

Wickelgren (34) showed marked increases in RI when he increased the phonetic similarity of the interpolated task to that of the previously learned material. This RI tended to prevent rehearsal, resulting in an information loss. Hunter's (35) review of RI leads him to comment:

It (RI) is by far the most potent factor in bringing about forgetting, and is often responsible not only for quantitative but also qualitative changes in what is remembered. The effects of interference increase with the amount of interpolated activity and with the similarity of this activity to the original; these effects show themselves most potent in the case of material which has not been well learned to start off with.

Proactive Inhibition

The effect of similarity in causing forgetting is much in evidence from proactive inhibition (PI). Decay theory (21, 25, 26) and interference theory (13, 28) both support the existence of a similar mechanism for PI. Decay theory specifies that the memory trace decays over the recall interval. Interference theory explains the increase of PI over a period of time as a function of either an intervening activity, or the spontaneous recovery of similar material which was suppressed at the time the new material was presented (19).

B.J. Underwood (36) reported that the degree of retention of a word list was strongly influenced by the number of previously learned lists. Highly practiced subjects showed a retention for the last list learned of only twenty-five percent or less, while naive subjects remembered as much as seventy-five percent.

The existence of proactive inhibition in LTM is well established, but there is some disagreement as to whether the principles governing

proactive inhibition in LTM and STM are essentially the same (37). Peterson and Peterson (27) tested recall for individual items after a number of short intervals. They found that forgetting progressed at varying rates depending on the amount of controlled rehearsal of the stimulus, and that little evidence of PI occurred. Murdock (38) expanded their experiment, and found that an appropriate interpolated activity caused increased forgetting of an individual item over a retention interval measured in seconds. His results did not provide specific support for either the decay theory or interference theory of forgetting. Keppel and Underwood (28) reported that with a modification of the Peterson and Peterson technique, the retention of consonant trigrams at the longer retention intervals decreased greatly with the number of prior items. This suggested that proactive inhibition effects develop rapidly in STM as well as in LTM.

Murdock (39) later studied the proactive inhibition effects in STM for paired associates utilizing sixty subjects tested on six lists of six pairs each. A list of six A-B pairs (common English words paired at random) was presented once, then retention of one of the six pairs was tested by presenting A as the cue for recall of B. Results summed over all retention intervals showed performance did not deteriorate with practice, and therefore, do not easily fit a PI interpretation of forgetting. Wickelgren (34) subsequently demonstrated that interference was a function of phonetic similarity of items, and emphasized the existence of both proactive inhibition and retroactive inhibition in STM.

Conrad (40) varied the retention interval after four consonants had been presented. He found more forgetting as a result of the longer

interval, but the main dependent variable tended to be the nature of the 'intrusions'. Errors tended to be acoustically similar to the correct letter, indicating a pronounced PI effect. He proposed a modified decay theory in which decay was a loss of discrimination, while recall was a process of discrimination of the available memory traces.

The evidence to this point tends to support the existence of proactive inhibition in both LTM and STM although the exact mechanism by which it operates is uncertain. Posner (19) postulates, "... that the rate of decay of the STM trace is a function of the similarity of items presented within a short time span." He calls this the 'Acid Bath' theory. It is a decay theory which predicts information loss over a period of time while the amount of interference governs the rate of such loss.

III. KINESTHESIS AND MOTOR PERFORMANCE

Physical educators have recognized for years that kinesthesia has some relationship to motor performance. However, despite extensive research, very little is really known about this position sense (41). Many definitions of kinesthesia are available. Young (42) said; "Kinesthesia is cognizance of bodily position and movements, i.e., the sense of muscular effort." Witte (43) regards kinesthesia, "... as the sense by which an individual becomes aware of the position of the body and body parts and the extent and force of the muscular contraction." Henry (44) strictly defines kinesthesia as, "... the perception or consciousness of one's own muscular responses." He also hypothesizes,

"... that accurate kinesthetic adjustment is possible in the absence of the perceptual discrimination."

Morgan (45) considers kinesthesia as a somatic sense with receptors located in the muscles, tendons, and joints. He suggests that the joint receptors supply most of the information about the movement and position of the limbs, and are being stimulated in every movement. Howard and Templeton (46) define kinesthesia, "... as the discrimination of the positions and movements of body parts based on information other than visual, auditory, or verbal."

Despite the lack of a precise definition, kinesthesia represents one of the most vital areas of physical education research (44). Perhaps the most practical solution to the problem of a common definition is to define kinesthesia in terms of the task itself. Wilberg (18) operationally defines kinesthesia in his experiment as, "... that particular mental sensation (input) generated by the gripping and twisting of a handle. Visual and auditory input relevant to the gripping and twisting, are totally absent."

Many investigators have attempted to determine the importance of the kinesthetic sense as it is related to the development of various motor skills (43). Henry's (44) study and review of kinesthesia led him to reject cutaneous pressure as an important aide to perception, but intimates that joint movement could have been a factor.

Research in motor performance has included attempts to measure kinesthesia comparing the highly skilled player versus the poorly skilled on a variety of tests including leg or arm raising, balancing, throwing, pointing, or striking at objects. Wiebe (47) found those

with training in movement had a more highly developed kinesthetic sense. Young (42), Cratty (48), and Roloff (49) measured the relationship between kinesthesia and motor learning. They conclude that players who scored high on motor ability tests also scored higher on tests of kinesthetic ability.

The importance of kinesthesia in the performance of a motor task is stressed by K.B. Start (50).

Kinesthetic awareness is a major means of learning. It provides information to an individual about his body movement and this in turn is subconsciously integrated with other cues to enable him to move smoothly and accurately about his every day activities.

Kohler (51) divided movements into kinesthetically and visually directed categories. The simplest, most familiar fell into the kinesthetically directed category. The more complex, or unfamiliar motions requiring exact placement of the body or its members were visually directed and had to be executed with care. The reliance of human performance on visual cues is illustrated by Honzik's maze experiments with normal, blind, and deaf rats (52). He stated; "Maze learning is impossible with none other than kinesthetic cues available."

Gagne and Fleishman (9) regard kinesthesia as an 'internal stimulus' and sensory cues such as auditory and visual as 'external stimuli'. They suggest motor-skill sequences are learned in their preliminary stage by emphasizing external cues, and that internal cues succeed them as the level of skill proficiency increases.

IV. VISUAL AND KINESTHETIC INFORMATION IN PERCEPTUAL-MOTOR SKILLS

Research in STM has nearly exclusively concentrated on verbal processes during perception and subsequent rehearsal of the information (20). An exception to this verbal emphasis in STM has been the research in simple motor tasks. Posner (1) states:

Many skills involve the retention of patterns of visual or kinesthetic information which may not be easily or completely encoded in words. ... Several recent studies of perceptual-motor skills have suggested that nonverbal information concerning the distance, form, and location of prior movements must be stored between successive trials. This type of storage of nonverbal material is called imagery.

Bilodeau, Sulzer, and Levy (53) utilized a lever-positioning task to investigate retention of a simple motor task over a period of time. Bilodeau and Levy (54) later tested for retention of levering habits, and found an initial brief period of rapid forgetting and a longer period in which changes were at first very slow.

Boswell and Bilodeau (55) tested the short-term retention of a simple motor task as a function of interpolated activity. The subject was guided to two targets on a lever-positioning device during pretraining, and during training initially asked to make an unguided move to the first target. After a twenty second retention period, the subject was required to repeat his last move. Two different types of interpolated activity were utilized during the retention period. One required the subject to retrieve a pencil off the floor and the other required the subject to return the lever to zero. The pencil retrieval proved detrimental to retention, and moving the lever back to zero did not.

Adams and Dijkstra (16) used a similar lever-positioning instrument

to determine if short-term retention of simple motor responses varied with the length of retention interval and with the number of practice repetitions or reinforcements. They found that accuracy of short-term motor recall was a decreasing function of time measured in seconds, and was increased by the number of reinforcements when the range was sufficiently large. These results supported the view that verbal and motor STM follow the same general laws, and suggest that information in this experiment was not stored in the form of verbal labels.

Other researcher's recognized the importance of studying the acquisition of a complex motor skill in terms of kinesthetic, verbal, and visual cues (56, 57, 58). Day and Singer (59) examined the proposal that kinesthetic judgments of position involve only the receptor elements in the joints and not the muscle receptors. They concluded that the determination of the kinesthetic spatial aftereffect is the 'spatial' property of stimulation, not muscular activity. Singer and Day (60) later studied the dissipation of kinesthetic aftereffects over thirty and ninety second stimulation periods. The rate of dissipation was greater for the shorter period than for the longer one.

Leonard West (61) examined vision and kinesthesia in the acquisition of a typewriting skill. His findings showed a swift rise in kinesthetic dependability from low levels among beginning typists. He interprets these results to suggest the free use of vision in early stages of learning to type, as contrasted with the so-called 'touch' system.

The role of kinesthesia in perceptual-motor learning was investigated by Fleishman and Rich (62). In their study, forty male subjects were administered two ability measures: a standardized test of spatial

orientation and a measure of kinesthetic sensitivity. Then they received extended practice on a 'Two-Hand Coordination' task. The findings confirmed their hypothesis that sensitivity to kinesthetic cues is more important later in perceptual-motor learning, while sensitivity to spatial-visual cues is more critical early in learning.

Posner (1) summarized that visual and kinesthetic information were stored differently in STM. He found that visual and kinesthetic cues were affected differently by an interpolated task. The difference in results did not appear to lie in the degree of verbalization but supported the view, "... that some memory tasks involve retention of information in non-verbal form and that such information is subject to forgetting which can be measured over time." Posner and Konick (20) demonstrated that both visual-location and kinesthetic-distance tasks showed orderly forgetting over delay periods from zero to thirty seconds. The conditions under which forgetting occurred however were very different. The kinesthetic task showed forgetting even during rest, and the rate was independent of the complexity of the interpolated task. The visual task showed no forgetting during rest, and extreme increases in forgetting as the interpolated task became more difficult. They conclude that in both tasks primary retention is through imagery rather than verbal codes, and "... that the memory systems used to retain information may be rather different from each other and from verbal materials." Posner (17) later replicated this study with the addition of tasks of visual-distance and kinesthetic-location. He confirmed that STM storage involved more than verbal labels and suggested that visual and kinesthetic STM codes have different processing requirements. In fact,

over a twenty second delay period with an interpolated classification task, kinesthetic cues provided less errors than those stored visually.

A similar experiment by Wilberg (18) loaded the kinesthetic factor of pressure (or torque) in conjunction with the visual tasks. He reported results which agreed with previous studies showing a rapid decay of STM due to an interpolated task. He further reported that performance based upon recall from visual and kinesthetic STM is not affected by the kinesthetic factor of constant pressure. He concludes, "... if such pressure (constant torque) is not used as a source of information about the re-positioning of a body segment, any kinesthetic construct concerning the same is suspect."

Experiments utilizing augmented feedback to increase the discernment of different movements support the hypothesis that response precision is limited by the evaluative accuracy of feedback information (2). Gibbs (63) used a free-moving joystick and a heavily spring-loaded joystick to control the position of a spot on a screen. The spring-loaded stick gave significantly better performance than the free-moving one. He concluded that the spring-loaded stick provided a position dependent signal to the subject, whereas the free-moving joystick did not. Similarly, Bahrick (64) showed that the addition of a spring to a control led to an improvement in blind positioning accuracy of the control.

A recent study by Norrie (65) investigated the absolute and directional changes in STM resultant from the exertion of a force. Subjects were required to push against a vertical steel bar attached to a pointer and handle. Maximum force calibrated was six kilograms or .4 inches on the scale, however the standard force used in the study

resulted in only .13 inches of bar movement. Experimental conditions consisted of reproduction of the initially directed force for immediate recall and three retention intervals of one-half, one and one-half, and four minutes. She concluded that there was no significant difference among the conditions for absolute error but that immediate reproduction produced a considerable algebraic error overestimation in comparison to the three other retention intervals.

V. SUMMARY

The essence of this review of the literature indicates the great interest being demonstrated by researchers in STM. This interest has resulted in definite statements and theories about the characteristics of the memory trace, the nature of memory and human learning, and the relationship between STM and LTM.

The role of kinesthesia in motor performance is not yet fully understood, yet this is an area of increasing importance to physical educators. A comprehension of the role visual and kinesthetic cues play in STM will contribute greatly to the improvement of human performance theory.

CHAPTER III

METHODS AND PROCEDURES

I. APPARATUS

The testing instrument used in this study was a rotary handle which developed an increasing pressure (torque) by compressing a torsion spring when rotated in a clockwise direction (see Figure 1). This apparatus is a manual lever, making use of discrete motor positioning responses. It permits the performance of a motor response without directly introducing a verbal component and is designed to measure the ability of the subject to assimilate visual and kinesthetic (increasing torque) cues in short-term memory (STM).

The apparatus, which was constructed by the University of Alberta Technical Services Center, consisted of a fixed metal disc with a one inch central shaft held in a ball-bearing casing. Fitted to the disc was a moveable plate which permitted the handle to be changed to eight different positions. Attached to one end of the central shaft was a six inch handle with a rotary grip. The handle was affixed to the central shaft by means of a keyway to facilitate removal. One end of the one and one-half inch torsion spring was attached to the moveable metal plate, and the other end to the rotary handle. Rotating the handle in a clockwise direction produced a gradual increase in torque as the spring was compressed. The torsion spring was specially manufactured of three-sixteenth inch high tension steel to insure high reproduction accuracy.

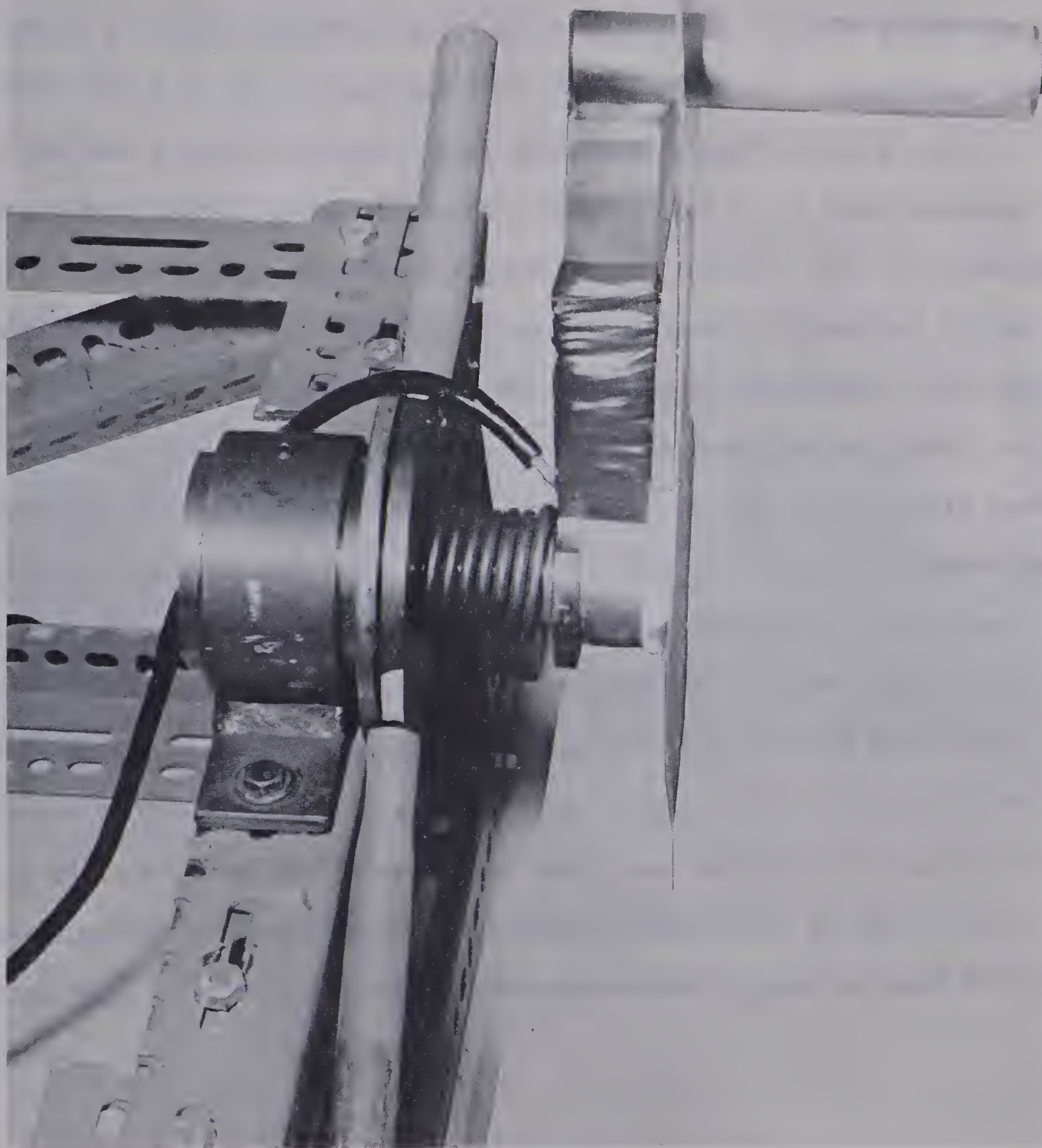


Figure 1. Isolated View of Rotary Handle Apparatus

The pressure on the handle was measured by a strain gauge connected through a voltage amplifier to an electric recorder (Strain gauge type FAP-50-12, S-6, with a resistance of $121.0 \pm .5$ ohms). The voltage amplifier was a Hewlett-Packard model 467A power amplifier set at plus or minus four volts. A Hewlett-Packard Moseley 680M strip chart recorder with limit switches recorded all experimental results. The limit switches were preset at the desired increasing torque levels. Connected to the limit switches were an amplifier, tone generator, and speaker which would produce a sound tone when the desired pressure level was attained. The amplifier was a Bogen 'Challenger' model CHB 20A, and the variable sound generator an Eico model 377. A cut-off switch was installed between the limit switches and tone generator to permit rapid control of the sound tone. A block diagram of the complete apparatus is shown in Appendix A. The entire apparatus, with the exception of the rotary handle, was hidden from the subjects view by a large screen. An offset twelve inch tin plate attached to the apparatus handle was designed to concentrate the subjects attention on the increasing torque aspect of the reproduction task. Figure 2 illustrates the experimental apparatus used in the study.

II. CALIBRATION

The test apparatus was calibrated by suspending a known weight at right angles to the handle. Rotation of the apparatus permitted additional weights, at two and one-half pound increments, to be added and maintained at the desired right angle. Keeping the hanging

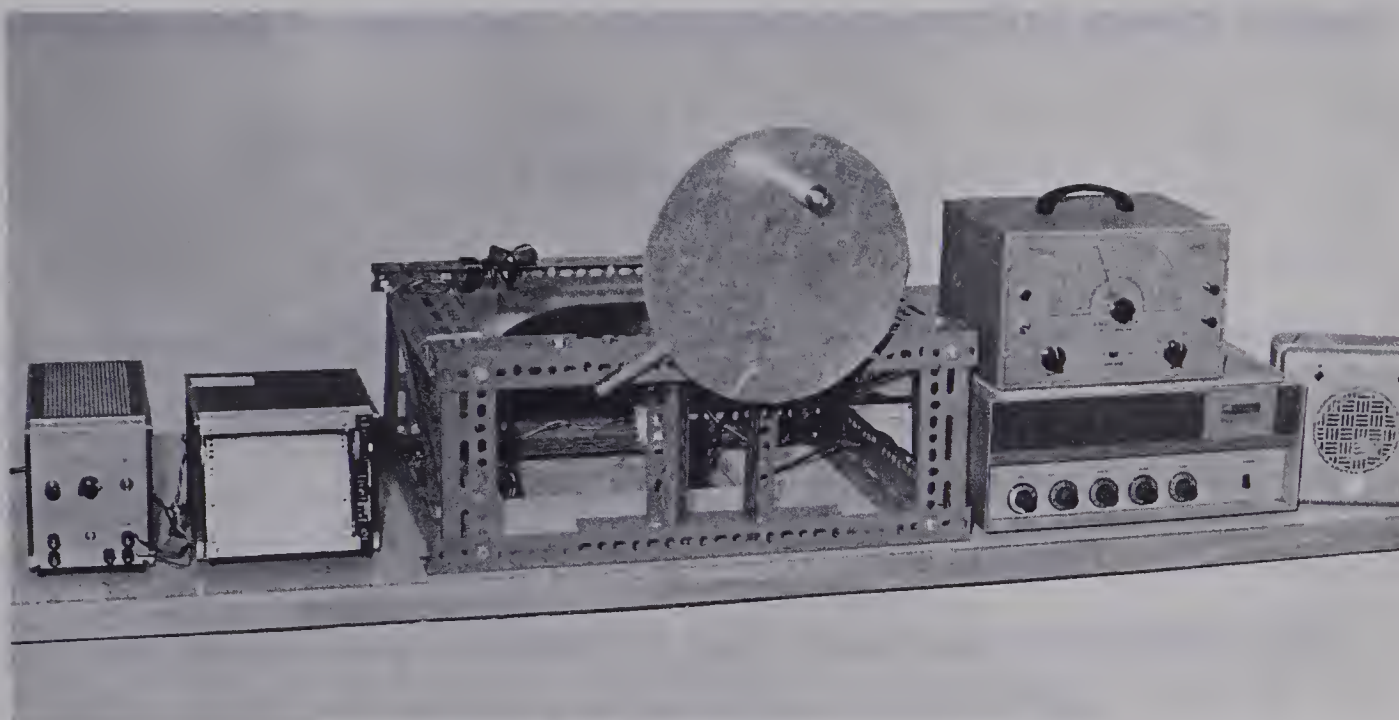


Figure 2. Increasing Torque Task Reproduction Apparatus

weight perpendicular to the handle permits the moment of the force about the axis to be a product of the weight and the perpendicular distance from the central shaft to the line of action of the force (66).

Graph recordings were taken to establish the various increasing torque factor levels. Subject data was then compared with the calibrated recordings to determine actual performance results in terms of absolute error measured in pound-feet. Calibration was verified between subjects.

III. EXPERIMENTAL DESIGN

The experimental design was a three factor, treatment by subjects, factorial, complete block fixed model and was randomized along all dimensions (see Figure 3) (67). To test whether the three factors of increasing torque were common to both visual and kinesthetic modalities, all combinations were presented in their visual and kinesthetic form.

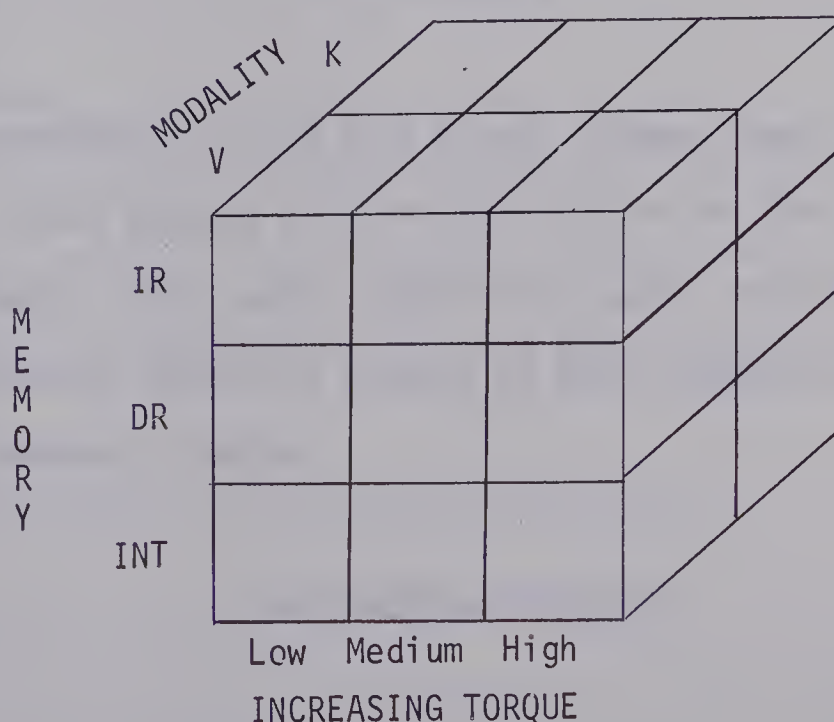


Figure 3. 3 x 3 x 2 Experimental Design

The three STM factors consisted of immediate recall (IR), delayed recall (DR), and delayed recall with an interpolated task (INT). All subjects were given three practice trials under each experimental condition and five repetitions per subject were recorded for these conditions. The increasing torque factors considered in all experiments were: (a) Low = zero - two and one-half pound-feet, (b) Medium = zero - five pound-feet, and (c) High = zero - ten pound feet. The eighteen combinations of increasing torque, sensory modality, and STM factors were randomly combined with the five repetitions per subject to yield ninety trials per subject. Each main effect comprised 270 trials while each experimental condition consisted of forty-five trials. Randomization was presented with replacement with one minute rest between test trials. Each subject performed thirty trials during three separate test periods.

IV. SUBJECTS

Nine seventeen year old high school students were used in this experiment. Each subject received two dollars per hour. All subjects were volunteers, right-handed, physically sound, and selected from the grade XII physical education classes at Ross Sheppard Composite High School in Edmonton, Alberta.

V. EXPERIMENTAL PROCEDURE

Immediate Recall Condition

Immediate recall of visual and kinesthetic information was recorded

in this experiment. The subjects were required to visually observe the handle when moving it, or to kinesthetically feel the handle when vision was prevented by wearing goggles. In both conditions, the subject released the lever on the limit switch sound tone. Upon releasing, the subject immediately turned 360 degrees on a swivel chair, while the experimenter randomly preset the handle to one of eight positions. The subject regripped the handle and attempted to reproduce the same pressure position. The limit switch sound tone was disconnected during this attempt.

Delayed Recall Condition

Delayed recall for both visual and kinesthetic conditions in STM was the subject of this experiment. The subject mentally rehearsed the replacement task for ten seconds.

Similar instructions to the immediate recall condition preceded this experiment. Upon releasing the handle, however, the subject turned 180 degrees, sat quietly for ten seconds while he rehearsed the task; then turned an additional 180 degrees, regripped the handle and once more attempted to reproduce the desired pressure position.

Delayed Recall with Interpolated Task Condition

Delayed recall with an interpolated task for visual and kinesthetic cues in STM was studied in this experiment. It was analogous to the delayed recall condition except for the addition of the interpolated task designed to prevent rehearsal of the memory trace. During the

ten second delay period the subject was required to count backward, aloud by three's, from 100.

VI. TREATMENT OF THE DATA

The statistical treatment selected for this experimental design was a three-way analysis of variance (ANOVA). A Fortran IV program computed on the IBM 360/67 computer at the University of Alberta was utilized to determine the statistical results.

The tests of significance used were the F-ratio and Duncan's New Multiple Range Test with the rejection level set at $\alpha = .01$.

CHAPTER IV

ANALYSIS

I. HYPOTHESES

Studies of visual and kinesthetic cues in short-term memory (STM) have not divulged the factors that seem to account for the apparent difference in storing and processing this information (1) (19). Loading the kinesthetic factor of increasing torque could provide additional knowledge of the processing and/or storage mechanism in STM.

Three hypotheses were formulated to structure this study.

1. H_1 : Immediate = Delayed < Delayed plus Interpolated

The first hypothesis deals with the relationship between the three STM factors of immediate recall, delayed recall, and delayed recall with an interpolated task. Research evidence (19) (20) indicated that the delayed and immediate recall factors would lose a similar amount of information, with the delayed recall and interpolated task factor sustaining an even greater loss. The amount of information loss would determine the accuracy of performance reproduction.

2. H_2 : Low = Medium = High

The second hypothesis was concerned with the three increasing torque factors set at two and one-half pound-feet, five pound-feet, and ten pound-feet. These factors were called low, medium and high respectively. Little guidance was available from the literature in this regard. Therefore, it was hypothesized that no significant difference would be found between the three increasing torque factors on a performance reproduction task.

3. H_3 : Visual < Kinesthetic except when visual and kinesthetic are delayed with an interpolated task.

The third hypothesis was a statement of the relationship that exists between the sensory modality factors of vision and kinesthesia. Posner (19) indicated that visual information was superior to kinesthetic information but illustrated a greater increase in forgetting as the interpolated task difficulty increased.

II. RESULTS

The analysis of this study was made under the assumptions of a 'fixed' model in which the main effects (STM, increasing torque, and sensory modality) and their interactions could be examined.

Analysis of Variance

A three-way analysis of variance was the statistical tool employed in the investigation of the main effects of STM, increasing torque, and sensory modality that resulted from the 3 x 3 x 2 experimental design. Table I is a summary of this analysis.

The only factor resulting in a significant F ratio was the main effect of increasing torque. This F of 177.29 was significant at $\alpha = .001$. No other main effects or interactions were significant.

Duncan's New Multiple Range Test on Main Effects

Statistical analysis in this experiment was not only limited to

TABLE I

THREE-WAY ANALYSIS OF VARIANCE - SUMMARY OF ALL SCORES
FOR MAIN EFFECTS AND INTERACTIONS

Source of Variation	SS	df	MS	F
Short-term Memory (STM)	.1401	2	.0701	.0556
Increasing Torque	446.7275	2	223.3638	177.2923*
Sensory Modality	.1647	1	.2182	.1307
STM X Increasing Torque	.8729	4	.1647	.1732
STM X Sensory Modality	.4130	2	.2065	.1639
Increasing Torque X Modality	4.8776	2	2.4388	1.9358
STM X Torque X Modality	1.8962	4	.4741	.3763
Error	997.8110	792	1.2599	

* Significant at .001 level.

	df	.05	.01	.001
Critical F Values	2,792	3.01	4.64	6.97
	4,792	2.39	3.35	4.67
	1,792	3.86	6.68	10.95

those effects in which the F ratio was significant. Winer (68) has stated that the specific comparisons which are the theoretical basis for the experiment should be examined individually, regardless of the corresponding F test. Therefore, a 'post hoc' test utilizing the Duncan's New Multiple Range Test (67) was undertaken to determine if absolute mean error performance on the reproduction task differed within each main effect. Tables II, III, and IV summarize these findings. From the range test analysis it is evident that the only significant difference among any of the main effects occurred in the increasing torque factor. The absolute mean error of the varying torque levels was progressively greater from low to medium to high levels.

TABLE II

DUNCAN'S NEW MULTIPLE RANGE TEST
APPLIED TO THE DIFFERENCE BETWEEN K = 3 MEANS
(SHORT-TERM MEMORY FACTORS)

Means	Delayed 1.2617	Interp. 1.2700	Immediate 1.2950	Shortest Significant R
1.2617		.0083	.0250	$R_2 = .2477$
1.2700			.0250	$R_3 = .2581$
1.2950				

Significant level = .01

TABLE III

DUNCAN'S NEW MULTIPLE RANGE TEST
APPLIED TO THE DIFFERENCE BETWEEN K = 3 MEANS
(INCREASING TORQUE FACTORS)

Means	Low .6300	Medium .9067	High 2.2900	Shortest Significant R
.6300		.2763*	1.6600*	$R_2 = .2477$
.9067			1.3833*	$R_3 = .2581$
2.2900				

* Significant at the .01 level.

TABLE IV

DUNCAN'S NEW MULTIPLE RANGE TEST
APPLIED TO THE DIFFERENCE BETWEEN K = 2 MEANS
(SENSORY MODALITY FACTORS)

Means	Kinesthetic 1.2722	Visual 1.2788	Shortest Significant R
1.2722		.0066	$R_2 = .2025$
1.2788			

Significant level = .01

Repetitions and Subjects

A five-way analysis of variance was performed with the addition of the two factors of repetitions and subjects. Excerpts from this analysis which was utilized merely as a diagnostic aid are shown in Table V.

TABLE V
EXCERPTS FROM THE FIVE-WAY ANALYSIS OF VARIANCE
SHOWING F RATIOS OF REPLICATIONS AND SUBJECTS

Source of Variation	SS	df	MS	F
Replications	.9591	4	.2398	.2352
Subjects	27.6131	8	3.4516	3.3855*
Replications X Subjects	58.8926	32	1.8404	1.8051
Error	130.5020	128	1.0195	

* Significant at .05 level

	df	.05	.01	.001
Critical F Values	4,128	2.44	3.47	4.62
	8,128	2.01	2.65	3.27
	32,128	1.54	1.83	2.05

Only the F ratio for subjects ($F = 3.39$) was significant at the .05 level of confidence, all other F's were non-significant.

An additional test of intercomparisons between repetitions and subjects was undertaken. These results are shown in Table VI. There was no significance for repetitions, while subjects ($F = 14.56$) were significant at the .01 level of confidence. Thus it would appear that while the subjects differed in their responses, they consistently responded in that manner during each replication.

TABLE VI
INTERCOMPARISONS FOR REPLICATIONS AND SUBJECTS
FROM FIVE-WAY ANALYSIS OF VARIANCE

Source of Variation	df	Calculated F	Critical F
STM vs Replications	2, 4	14.6086	18.00
Increasing Torque vs Replications	2, 4	.0045	18.00
Sensory Modality vs Replications	1, 4	6.2058	21.20
Subjects vs Replications	8, 4	.2954	14.80
STM vs Subjects	2, 8	14.5612*	8.65
Increasing Torque vs Subjects	2, 8	.0045	8.65
Sensory Modality vs Subjects	1, 8	6.1926	11.26
Repetitions vs Subjects	4, 8	4.2520	7.01

* Significant at the .01 level

Primary Main Effect, Main Effect Factors and Experimental Condition Means

The three main effects of STM, increasing torque, and sensory modality were categorized into primary main effects of vision and kinesthesia

and major factor and experimental condition absolute error means on the performance reproduction task. The absolute mean error for each primary main effect, main effect factor, and treatment condition is illustrated in Tables VII and VIII respectively.

TABLE VII
ABSOLUTE POUND-FOOT ERROR MEANS FOR
THE PRIMARY MAIN EFFECTS AND MAIN EFFECT FACTORS

Main Effect Factor	VISUAL EFFECT	KINESTHETIC EFFECT	
	Mean	Mean	Accumulated Mean
Increasing Torque - Low	.66	.60	.6300
Increasing Torque - Medium	.82	.99	.9067
Increasing Torque - High	2.36	2.22	2.2900
STM - Immediate Recall	1.33	1.26	1.2950
STM - Delayed Recall	1.21	1.31	1.2617
STM - Delay with Interpolated Task	1.30	1.24	1.2700
Accumulated Mean	1.2788	1.2722	

These results are further interpreted in Figures 4, 5, 6, 7, 8, 9, 10. The specific experimental condition means plotted on each graph are indicated to facilitate interpretation and analysis.

TABLE VIII
ABSOLUTE POUND-FOOT ERROR MEANS
FOR THE EIGHTEEN EXPERIMENTAL CONDITIONS IN THE 3 x 3 x 2 DESIGN

Experimental Condition	Mean Error
Visual - Low Torque Level - Immediate Recall	.60
Visual - Low Torque Level - Delayed Recall	.70
Visual - Low Torque Level - Interpolated Task	.68
Visual - Medium Torque Level - Immediate Recall	.83
Visual - Medium Torque Level - Delayed Recall	.85
Visual - Medium Torque Level - Interpolated Task	.78
Visual - High Torque Level - Immediate Recall	2.55
Visual - High Torque Level - Delayed Recall	2.08
Visual - High Torque Level - Interpolated Task	2.44
Kinesthetic - Low Torque Level - Immediate Recall	.57
Kinesthetic - Low Torque Level - Delayed Recall	.62
Kinesthetic - Low Torque Level - Interpolated Task	.61
Kinesthetic - Medium Torque Level - Immediate Recall	1.07
Kinesthetic - Medium Torque Level - Delayed Recall	1.00
Kinesthetic - Medium Torque Level - Interpolated Task	.91
Kinesthetic - High Torque Level - Immediate Recall	2.15
Kinesthetic - High Torque Level - Delayed Recall	2.32
Kinesthetic - High Torque Level - Interpolated Task	2.20

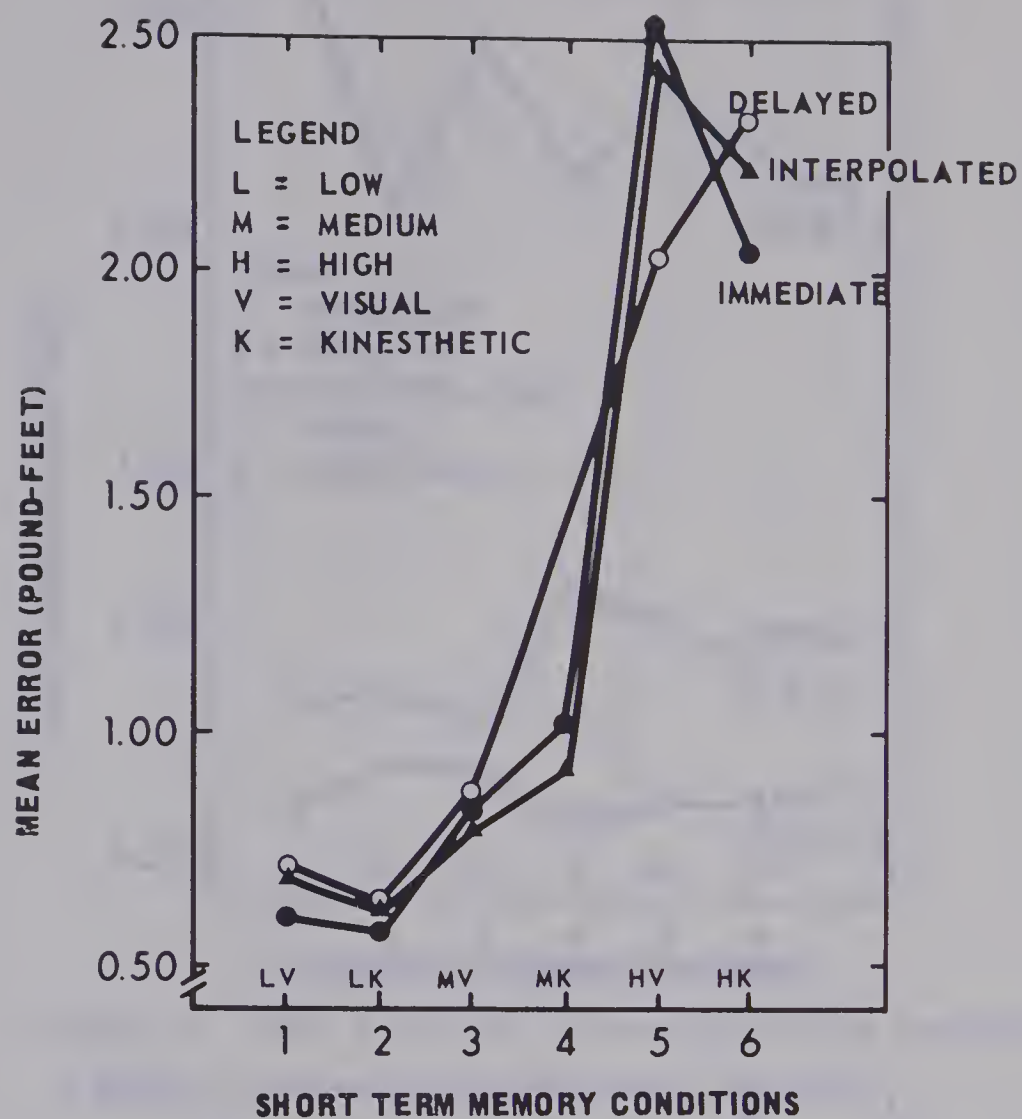


Figure 4. Mean Error for Short-Term Memory Conditions

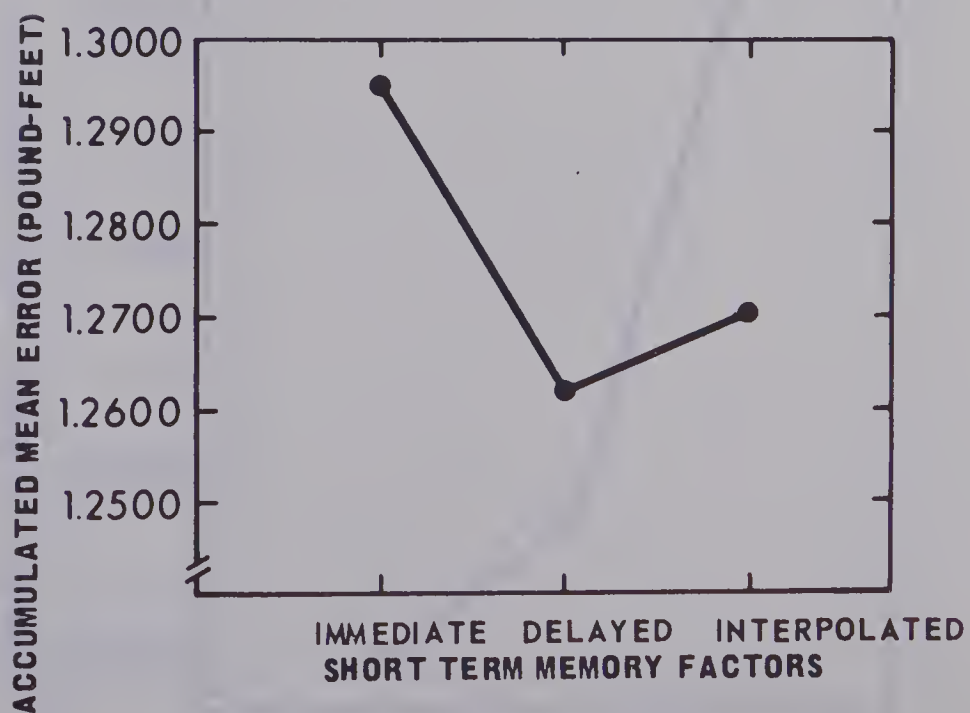


Figure 5. Accumulated Mean Error for Short-Term Memory Factors

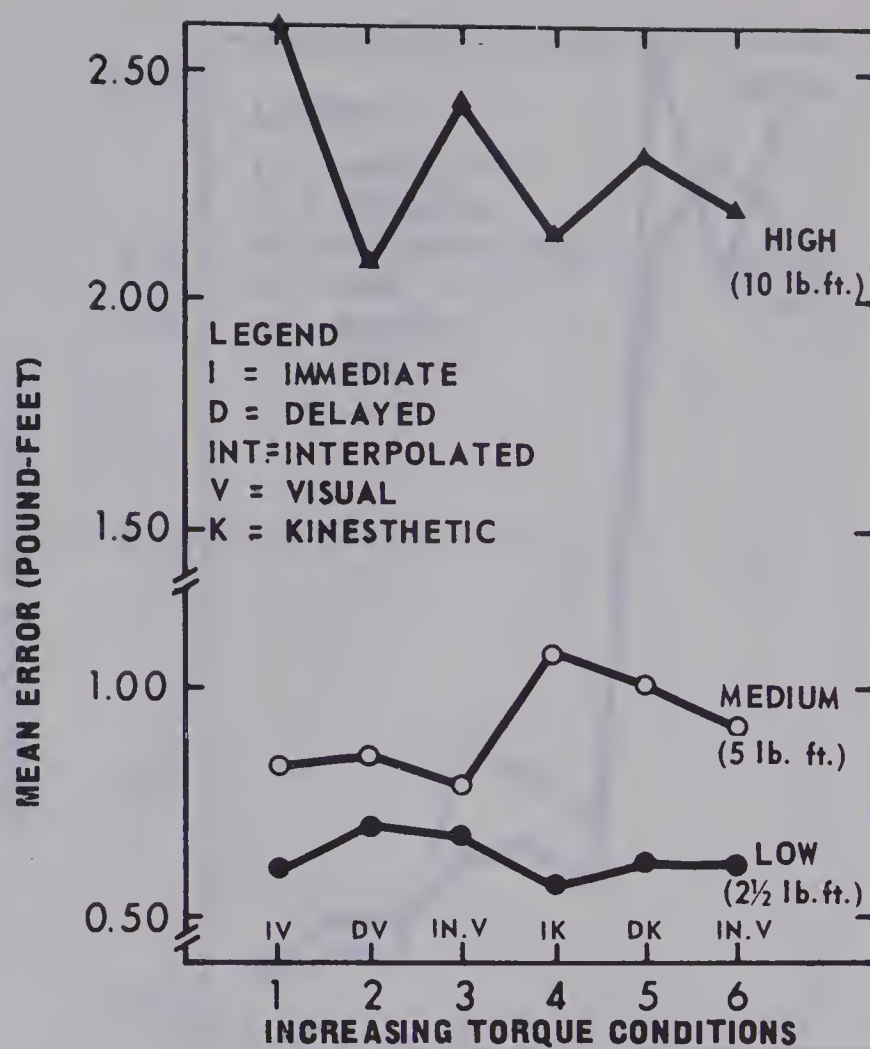


Figure 6. Mean Error for Increasing Torque Conditions

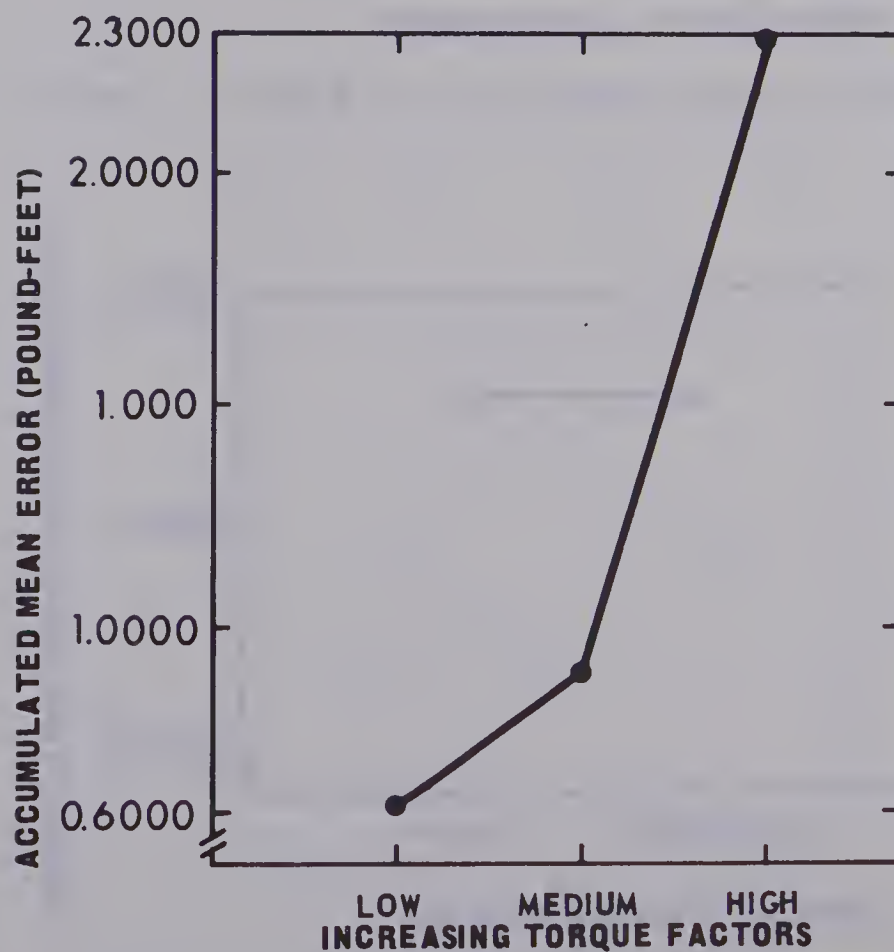


Figure 7. Accumulated Mean Error for Increasing Torque Factors

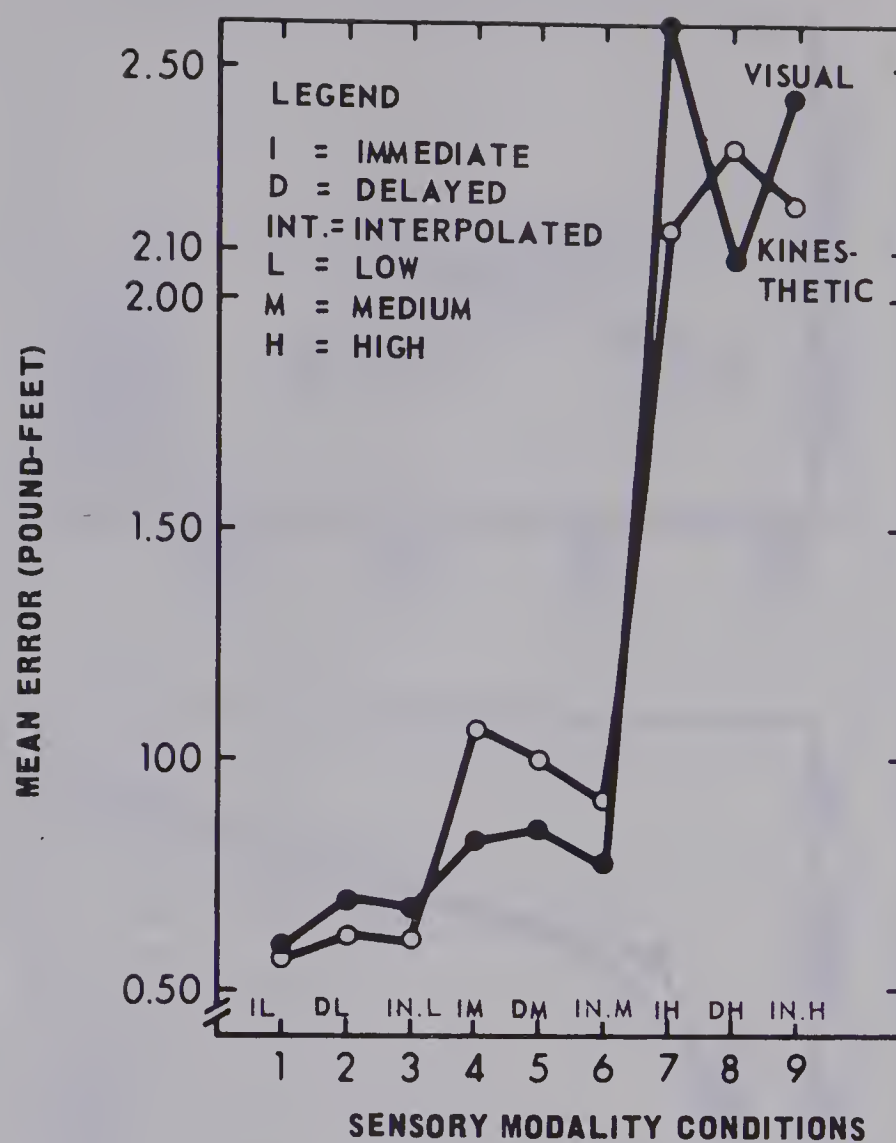


Figure 8. Mean Error for Sensory Modality Conditions

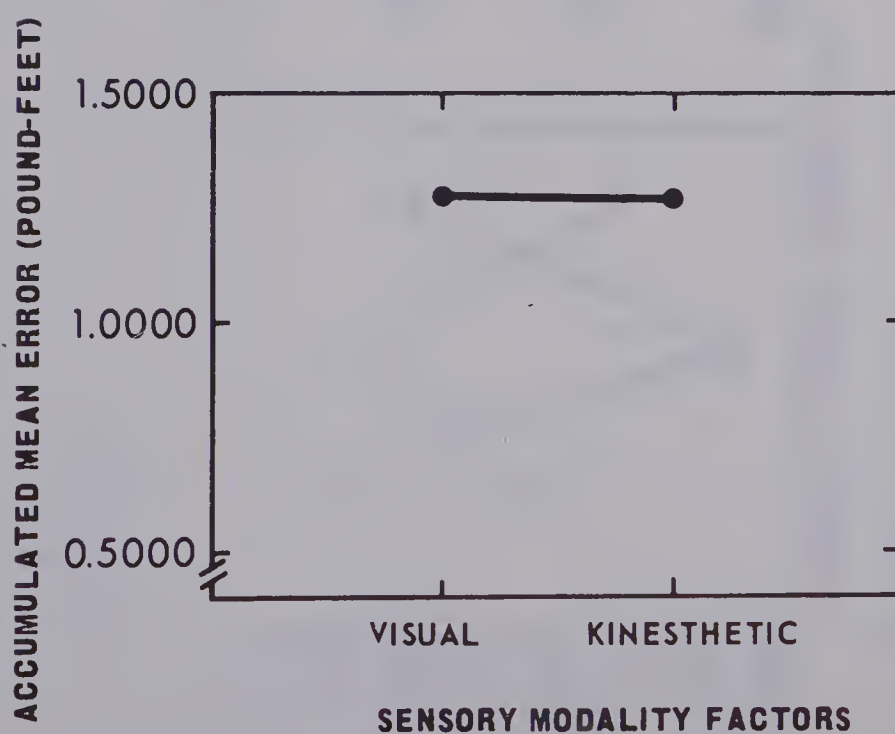


Figure 9. Accumulated Mean Error for Sensory Modality Factors

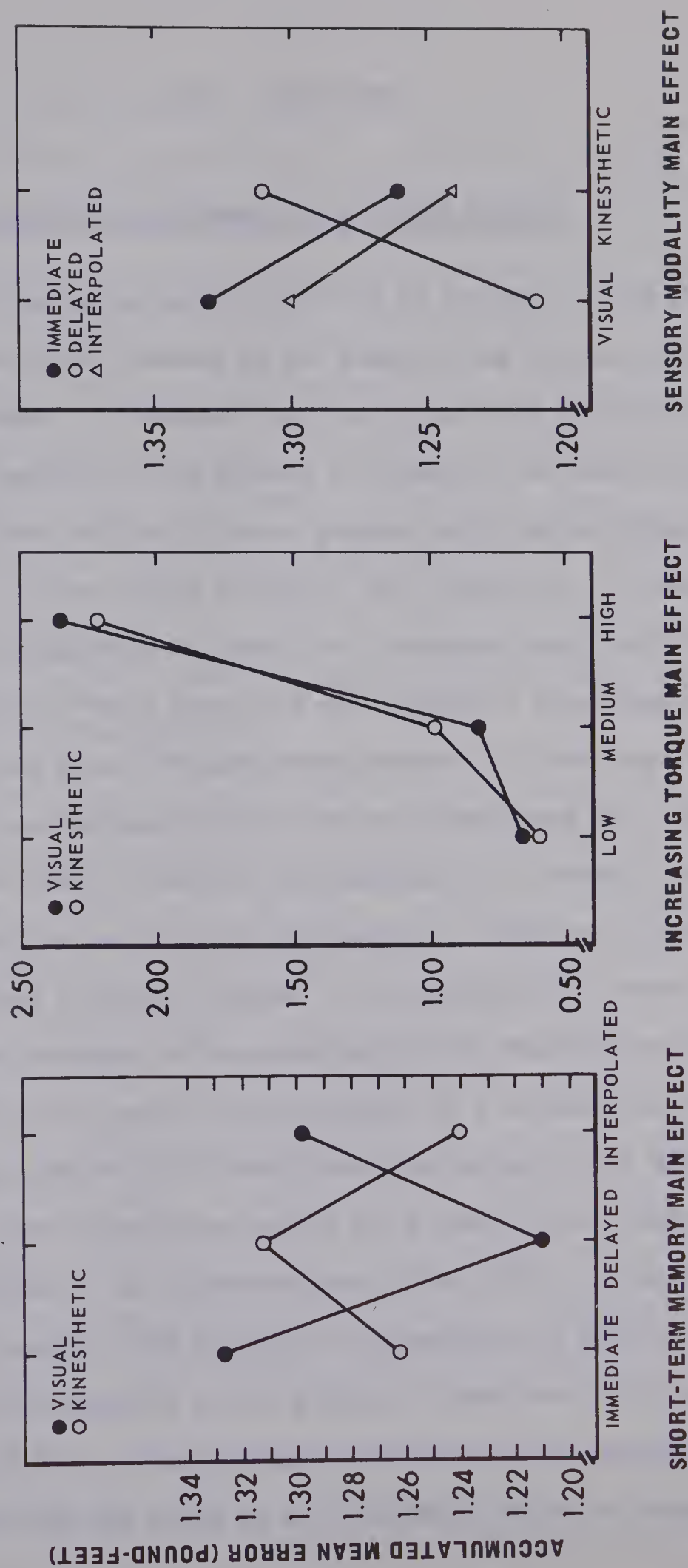


Figure 10. Accumulated Mean Error Emphasizing Primary Main Effects of Vision and Kinesthesia

III. DISCUSSION

Relationship of Short-Term Memory Main Effect Factors

Recent research by Posner (17) (19) in the area of STM and motor performance has given impetus to the study of the storage and processing etiology involved. It appears that both visual and kinesthetic information decay rapidly in the absence of rehearsal and that the degree of interpolated task difficulty has a greater debilitating effect on visual information. At the limits of STM in fact, retention of kinesthetic information was superior to visual in a selected motor skill (15).

The results of this study did not indicate a significant difference between the three STM main effect factors of immediate recall, delayed recall, and delayed recall with an interpolated task (Table I). The range test seen in Table II corroborated this finding. In Figure 5 a high immediate recall error followed by a reduction in delayed recall error and a slight increase in interpolated task error is indicated. The existence of the relatively high immediate recall error may have been due in part to the existence of a kinesthetic aftereffect (KAE). Singer and Day (60) found that dissipation of the KAE was very rapid for a short stimulation period and slower for the longer periods up to 240 seconds. The interpretation of the KAE as an important factor in immediate recall error would be in agreement with Norrie's (65) findings in her investigation of the effects of absolute and directional changes in STM for a kinesthetically monitored force reproduction task. She concluded that KAE could be an influencing factor on immediate

reproduction of performance.

The existence of increased error on verbal tasks due to a rise in interpolated task difficulty has been reported by Posner and Rossman (69). The existence of similar findings in STM for motor responses was also revealed by Boswell and Bilodeau (55) and Posner (17). In fact, Posner and Konick (20) provided evidence for the existence of information retention in both visual and kinesthetic conditions in the form of verbal coding and non-verbal imagery. It could be deduced from the results of the present study that visual coding was not as effective as kinesthetic coding during the immediate recall condition (see Figure 10). This may have resulted from more effective imagery during the kinesthetic immediate recall conditions.

The reduced error in delayed recall could be regarded as a result of trace consolidation in the form of verbal and non-verbal coding combined with a reduction in the effects of proactive inhibition. The increase in mean error from delayed recall to delayed recall with an interpolated task (see Figure 5) was expected as a result of the Posner studies (17) (19) (20). The proposed hypothesis relating to the STM main effect was therefore not justified in its entirety according to the results of this study. Evidence has been presented which suggests that STM storage and processing for a simple motor skill involving an increasing torque component as a kinesthetically dependent variable does not follow the same paradigm as for simple verbal tasks.

Relationship of Increasing Torque Main Effect Factors

Bahrack (64) and Gibbs (63) indicate that increasing the tension on a joystick by the addition of a spring provided a positional dependent signal to the subject. However, the lack of research specific to the effects of varying increasing torque levels on performance replication in STM led to a postulation of equal performance results for low (two and one-half pound-feet), medium (five pound-feet), and high (ten pound-feet) increasing torque levels. Justification for this premise was Wilberg's (18) analysis of constant torque loads and STM in which he found no effect on recall for visually or kinesthetically stored material.

The main effect of increasing torque was significant at $\alpha = .001$ (see Table I). A range test on the main effect factors for this variable was made. The results appear in Table III. Evidently increasing torque appears to be a very important factor in analyzing the effects of visual and kinesthetic cues on STM. The extreme nature of the mean error differences (Table VII and Figures 6 and 7) for increasing torque, particularly at the high level, suggested that the highest factor of this main effect was suppressing the entire main effect. Consequently, a further three-way analysis of variance was performed omitting the highest factor level of the increasing torque main effect. A comparable F ratio result was obtained, with increasing torque being the only significant factor among all main and interaction effects.

Reproduction accuracy was therefore highly modified by the increasing torque main effect. It would appear from this study (Figures 6 and

7) that there is a limit to the amount of increasing torque to which the subject can attend with any degree of reproduction accuracy. The medium and high levels resulted in increasingly larger errors in reproduction. The information, both visual and kinesthetic which was contained in this motor task appeared to overwhelm the subjects, resulting in poor performance. The STM store seemed capable of processing only a certain proportion of the perceived input information. This difficulty at the STM level may not be due entirely to an overwhelming source of information but in part to a poor encoding process of both verbal and non-verbal (imagery) information.

It is significant to note that the proportionate mean error for all conditions in each increasing torque factor was approximately the same; .252, .181, and .229 for low, medium and high increasing torque factors respectively (see Table IX). This is a further indication that the STM system may be capable of storing and/or processing only a certain proportion of increasing torque input information regardless of the torque level perceived.

TABLE IX
PROPORTIONATE MEAN ERROR
FOR EACH INCREASING TORQUE FACTOR

Factor	Accumulated Mean Error	Proportion
Low (2-1/2 lb. ft.)	.6300	.252
Medium (5 lb. ft.)	.9067	.181
High (10 lb. ft.)	2.2900	.229

The hypothesis that no significant difference would be found between the increasing torque factors was discounted as a result of this study. It would appear from the levels used that increasing torque was a highly significant factor in performance reproduction.

Relationship of Sensory Modality Main Effect Factors

The apparent storage disparity in STM for visual and kinesthetic information reported by Posner (19) resulted in the hypothesis that the visual conditions should be superior to the kinesthetic except at the delayed recall with interpolated task level. The mean errors for conditions and accumulated mean errors for main effect factors and primary main effects shown in Tables VI and VII do not entirely support this premise. In fact, the slope of the graph in Figure 9 is indicative of almost identical scores for both visual and kinesthetic conditions, with the kinesthetic factor being slightly less than the visual factor. However by plotting sensory modality as a primary main effect against STM and increasing torque the expected lessening of kinesthetic factor error in relation to visual as a result of delayed recall with an interpolated task becomes apparent (see Figure 10).

The higher error scores for the visual factor during the immediate performance reproduction could be attributed to the overwhelming sources of both verbal and non-verbal information which had to be processed in the STM store during the initial recall period. The immediate effects of proactive inhibition discussed by Posner (19) are also a negating factor. The increase in kinesthetic error over visual during the delayed

recall condition (see Figure 10) can be attributed to the consolidation of the memory trace and reduction in proactive inhibition.

No justification for acceptance of the hypothesis as stated was obtained from this experiment. Kinesthetic information appeared to be as significant as visual in the performance of a simple motor task involving increasing torque as a kinesthetically dependent variable.

Relationship of Replication and Subject Factors

Excerpts from the five-way analysis of variance were utilized to diagnose the effects of replications and subjects (Table V). The only significant F at even the .05 level was reported for subjects ($F = 3.39$). This was interpreted to mean the subjects were significantly different from each other but treated all replications in a similar manner.

The test of intercomparisons ($F = 14.56$) indicated that while the subjects differed in their responses they did respond consistently in the same manner for each replication (see Table VI).

General Discussion

The main effect of STM factors was insignificant in this study. This lead to a general rejection of the previously stated hypothesis that immediate and delayed recall factors would be similar and less than the delayed recall with an interpolated task factor. The disparity between the stated hypothesis and results obtained in the study is explained in part by the existence of a kinesthetic aftereffect, particularly evident during immediate recall, and the presence of proactive

inhibition. The addition of the interpolated task did produce the expected reduction in performance reproduction accuracy as noted by Posner (19).

The main effect of increasing torque was highly significant. The results of this study support the acceptance of increasing torque as a highly significant factor in the storage and processing of information in STM. The hypothesis that no significant difference would exist between the three error means of the increasing torque factors was therefore rejected.

Sensory modality as a main effect was insignificant in the present experiment. This was generally contrary to the expected result except during the delayed recall with interpolated task condition. The similarity between visual and kinesthetic factor results is an indication of either providing an overwhelming source of information which must be assimilated by STM, an erroneous encoding system, or the visual factor may not provide additional useable information in a simple motor reproduction task involving increasing torque as the kinesthetically dependent variable.

CHAPTER V

SUMMARY AND CONCLUSIONS

I. SUMMARY

The purpose of this study was to investigate the effect of increasing torque as a kinesthetically dependent variable on the apparent storage disparity between visual and kinesthetic cues in short-term memory (STM). The experimental design was a $3 \times 3 \times 2$ treatment by subjects, complete block fixed model, and was randomized along all dimensions. The three main effects of STM, increasing torque and sensory modality were examined under the eighteen experimental conditions dictated by the stated paradigm. Five repetitions per condition resulted in ninety trials per subject. The nine subjects used were volunteers from the grade XII physical education classes at Ross Sheppard Composite High School in Edmonton, Alberta. Each subject was male, right handed, and seventeen years of age.

The subjects were required to reproduce a predetermined pressure position by rotating the handle of a crank which compressed a torsion spring producing an increasing torque. The crank handle was randomly repositioned in one of eight positions between reproduction trials. A strain gauge attached to the shaft of the crank handle electrically recorded the amount of torque on a strip chart recorder. Each task was randomly performed under both visual and kinesthetic conditions.

The STM main effect consisted of immediate recall, delayed recall (ten seconds), and delayed recall with an interpolated task (counting

backwards aloud by three's, from 100 for ten seconds). The increasing torque main effect was broken down into three factors; low - 'two and one-half pound-feet', medium - 'five pound-feet', and high - 'ten pound-feet'. The sensory modality main effect comprised the two factors of vision and kinesthesia. Each subject was provided with goggles during the kinesthetic conditions and performed the same tasks without goggles during the visual conditions.

The specific problems examined in the study were directly related to the concept of a potentially different STM etiology for visual and kinesthetic information. They included:

1. The relationship that exists between the visual and kinesthetic STM factors of immediate recall, delayed recall, and delayed recall with an interpolated task resultant from the reproduction of an increasing torque simple motor task.
2. The effect of increasing torque as a kinesthetically dependent variable on STM storage and/or processing.
3. The relative importance of both visual and kinesthetic modalities in STM retention of an increasing torque reproduction task.

Three hypotheses were formulated to structure the analysis of these problems. The first hypothesis stated that no significant difference would occur between the STM factors of immediate and delayed recall, and that both would be more accurate than the delayed recall with interpolated task factor. The second hypothesis indicated that no significant difference would occur between the three increasing torque factors. The third hypothesis stated that retention of visual information would be superior to kinesthetic information in STM, but would show a greater

increase in forgetting as a result of an interpolated task.

II. CONCLUSIONS

Within the confines and limitations of the sample group, experimental procedures utilized, and statistical analysis performed, a number of conclusions are justified.

The reproduction accuracy on an increasing torque motor task does not appear to follow the same STM paradigm as for simple verbal tasks. It would seem that immediate STM reproduction error is increased as a result of an overwhelming information flow, and a kinesthetic aftereffect. This is further evidenced by the increase in visual error over kinesthetic error during immediate recall. The existence of a pronounced kinesthetic aftereffect might be explained by subject concentration on increasing torque rather than visual location as the cue for position reproduction. The STM system appears to consolidate the memory trace during a ten second delay period reducing visual mean error in relation to kinesthetic error. The increase in visual over kinesthetic absolute mean error due to the delayed recall with an interpolated task factor was further evidence of the existence of a different storage and/or processing procedure employed by the STM system in assimilating visual and kinesthetic information.

Increasing torque appears as a significant kinesthetically dependent variable in reproduction of the simple motor task utilized in this study. The subjects seem to attend to the difference in increasing torque level as an important source of information in task reproduction.

The visual and kinesthetic sensory modalities seem to be affected equally by the increasing torque factor. The kinesthetically dependent cues produced by the increasing torque component seem to provide the most highly utilized information during the STM retention period studied. Visual cues during this period do not appear to provide a great deal more usable information. This may be due in part to the overwhelming amount of information presented to the STM store by the kinesthetic cues. Because the subjects were told to cue on increasing torque, and visual-distance location was not possible due to randomization of the handle position prior to replication, the kinesthetic cues appear to become dependent cues in the STM system. Cuing may be in the form of imagery rather than verbal cues during the performance of a simple motor task utilizing increasing torque as the kinesthetically dependent variable.

III. RECOMMENDATION

The previous discussions and conclusions based on the results of this study indicate that the concept of increasing torque as a kinesthetically dependent variable should be tested over a wider pressure increment range. It may be that the information stored and processed in the STM system resultant from the increasing torque factor is limited by the particular pressure level used. A knowledge of these limitations is necessary to further define the STM construct.

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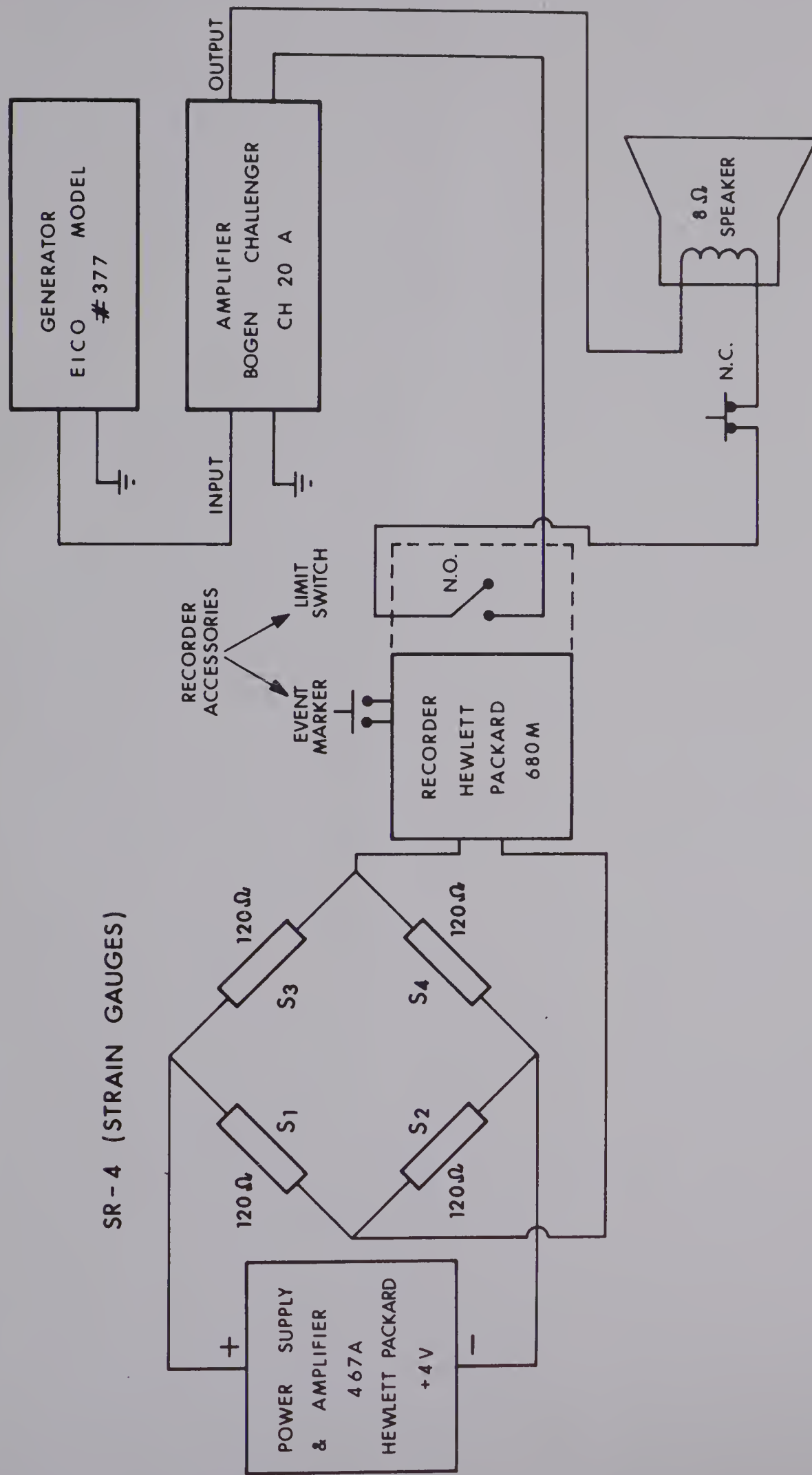
APPENDIX



APPENDIX A

APPARATUS BLOCK DIAGRAM





INCREASING TORQUE MEASURING DEVICE

Instrumentation Block Diagram

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